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ABSTRACT

This study examined the collegiate production and cost structures of the 28 universities in Turkey in order to estimate their degrees of economies of scale and scope. Multi-product cost functions were estimated for the collegiate production of teaching and research in order to determine the most efficient level and product-mix for differing types of colleges and for each individual university in Turkey. Three clusters of collegiate fields (social, health, and engineering sciences) were examined across 186 faculties within 28 universities through the use of a four-output quadratic cost function: undergraduate teaching, master and doctoral graduate levels of instruction, and research productivity. At the collegiate level, both ray- and product-specific economies of scale and global economies of scope were estimated. The data suggest that the scale and output-mix are the main determinants of the cost of teaching and research outputs. In addition the findings suggest that: (1) average incremental and marginal costs are generally highest for graduate instruction and research outputs and lowest for undergraduate instruction; (2) of the three fields, social sciences has the lowest costs across all categories and health sciences has the highest; (3) although costs generally follow levels of instruction, there are some significant exceptions, and (4) most outputs have shared resource uses and costs. (Contains 42 references.) (Author/JB)

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ECONOMIES OF SCALE AND SCOPE IN TURKISH UNIVERSITIES

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This paper was presented at the annual meeting of the Association for the Study of Higher Education held at the Doubletree Hotel, Tucson, Arizona, November 10-13, 1994. This paper was reviewed by ASHE and was judged to be of high quality and of interest to others concerned with the research of higher education. It has therefore been selected to be included in the ERIC collection of ASHE conference papers.

ECONOMIES OF SCALE AND SCOPE IN TURKISH UNIVERSITIES

ABSTRACT

The study reported in this paper examines the collegiate production and cost structures of the entire population of 28 universities in Turkey in order to estimate their degrees of economies of scale and scope. Multiproduct cost functions are estimated for the collegiate production of teaching and research in order to determine the most efficient level and product-mix for differing types of colleges and for each individual university in Turkey. Three clusters of collegiate fields (i.e., the social, health, and engineering sciences) are examined across 186 college faculties within 28 universities through the use of a four-output (i.e., undergraduate teaching, master and doctoral graduate levels of instruction, and research productivity) quadratic cost function. At the collegiate level, both ray- and product-specific economies of scale and global economies of scope are estimated. Estimates are given as to the most efficient level and mix of all outputs. The findings should help policy makers in Turkey determine whether some higher education institutions can reap efficiencies by an expansion (or contraction) of their outputs at different levels and by producing more (or less) teaching and research outputs jointly. Recommendations for priorities in the allocation of resourses to higher education in Turkey are given for policy makers.

ECONOMIES OF SCALE AND SCOPE IN TURKISH UNIVERSITIES

During the past two decades economic growth, strong social demand, and high priority in governmental policy for opening up access in postsecondary education have fueled a major expansion of the higher educational system in Turkey and the creation of many new universities and programs. Throughout this expansion, however, little attention has been given to the costs and productivity of such institutions. Little is known about either the internal or relative efficiency of any of these schools.

This paper examines the cost and production structures of all 28 universities in the national higher education system of Turkey. Three broad subject groupings (i.e., in the social science, engineering, and health science fields) are examined within each of the universities in order to estimate the extent to which economies of scale and scope might exist within their production of teaching and research activities. More specifically, the paper examines and reports on findings relative to two sets of questions. A first set of questions relates to whether there are ray- and product-specific economies of scale within and across individual faculties (or colleges) within the three broad subject groupings. A second set examines whether there are global economies of scope within and across individual colleges. Estimates are given as to the most efficient levels and mix of all outputs by type of field.

The study directly examines the following questions: (1) What are the average incremental and marginal costs of different outputs in different types of colleges? (2) Are there ray- and product-specific economies of scale at collegiate levels? If so, which colleges and fields should expand (or contract) in order to achieve these efficiencies? (3) Are there global and product-specific economies of scope within individual colleges with regard to the joint production of multiple output? Are there complementarities among four types of outputs (i.e., undergraduate instruction, master and doctoral graduate teaching, and faculty research) through their joint production? Should production be diversified, or should some types of colleges and institutions concentrate on undergraduate teaching and others on graduate instruction, and/or research for most cost-effective results? (4) Does the field or type of collegiate production (e.g., social science or engineering) influence costs and efficiency? If so, do different colleges or institutions vary in their prospective economies of scale, scope, and marginal costs? (5) What are the optimum levels and mix of outputs for different types of colleges? (6) How does the quality of a college and its product(s) effect its costs?

Theoretical Framework and Prior Research

Much research has been done in the area of cost functions in the field of economics since the turn of the century. These studies have provided important information in many sectors of the economy about decision making with respect to efficient resource allocation. On the other hand, estimating cost functions in higher education has been quite limited until only recently. Spurred especially by the expansion of higher education in most developed countries during the 1960s, concern with increasing efficiency in higher education has generated a number of studies that attempt to estimate the cost functions of higher education institutions (see, for example, Brovender, 1974; Maynard, 1971; Smith, 1978; Southwick, 1969; Tierney, 1980; Verry & Davis, 1976). However, a major problem found within almost all these earlier studies was their assumption that production could be characterized by a single homogeneous output (measured almost always by undergraduate student credit hours). James (1978) has noted, for example, that the failure in previous studies to adjust correctly for the substantial allocation to research and graduate training has apparently meant that undergraduate costs have been overstated, the social rate of return to undergraduate costs have been understated, and estimates of productivity growth through time have been understated (p. 184).

This limited attention to the multiproduct nature of higher education has not been due to any lack of interest on the part of economists or higher education policy analysts in examining multiproduct cost functions. Rather, the lack of appropriate econometric models for explaining the nature of multiproduct firms has been the foremost problem preventing the analysis of multiproduct firms in business and industry, as well as in non-profit organizations such as higher education. Fortunately, recent developments in the field of economics relative to the theory of industrial organizations in their production processes permit an endogenous determination of the cost structures of multiproduct firms. Over the past eight years an outpouring of empirical studies using multiproduct cost concepts have provided insights into the cost behavior and technology of multiproduct firms in a wide range of industries, including banking, transportation, telecommunication, petroleum, and hospitals among others (see, for example, Shoesmith, 1988; Wang & Friedlaender, 1985). The econometric modeling and use of quadratic equations for estimating multiproduct production and cost functions by Baumol and his colleagues (1988) was an especially important contribution.

From this theoretical foundation developed in economics, six recent studies have examined the multiproduct nature of production and costs in U.S., U.K., and Australian higher education (Cohn, Rhine & Santos, 1989; de Groot, McMahon & Volkwein, 1991;

Nelson & Neverth, 1992; Dundar & Lewis, in press; Lloyd, Morgan & Williams, 1993). Although the studies by Cohn et al (1989) and de Groot et al (1991) represent major advances in our understanding of costs in higher education, especially in their attempts to estimate economics of scope, both used only aggregated institutional level data as their unit of analysis. Other cost studies in higher education found that costs differ materially across academic fields and disciplines in relation to their outputs (Carlson, 1972; Berg & Hoenack, 1987) and that using only institutional level data can be misleading. Aggregating costs and outputs at the institutional level may yield unreliable generalizations concerning costs of some outputs and the existence of economies of both scale and scope. Adapting the most recent multiproduct methodology of Baumol et al (1988), Nelson and Neverth (1992) did focus on departmental data while examining the marginal costs of teaching outputs and for the possible existence of economies of scale and scope in the U.S.. However, their study utilized data from only a single university and consequently has limited generalizability. More recently, Dundar and Lewis (in press) adapted the multiproduct methodology of Baumol and focused on departmental data from 18 public research universities in the U.S. The present study, with a focus on the entire system of university education in Turkey, is an adaptation of the methodology employed in the earlier Dundar and Lewis U.S. study.

Although much attention recently has been given to related issues of costs in the delivery of higher education in many developed countries, most developing countries have very limited understandings about their costs of higher education. Such countries typically pay little or no attention to potential weaknesses and inefficiencies within their postsecondary institutions. Although historically there have been almost no empirical based studies dealing with the costs of higher education in developing countries (Tsang, 1987), recent interest by the World Bank in such issues has stimulated a few studies during the past decade (see, for example, Psacharopoulos, 1980; Hinchliffe, 1985; World Bank, 1986). It is instructive to note that all of these recent studies found significant opportunities for economies of scale with respect to undergraduate enrollments (i.e., all of the studies concluded that there could be substantial cost savings in per student expenditures if current levels of enrollment were to be raised).

In the case of Turkey, even as there are increasing concerns about costs and possible inefficiencies within the higher educational system, little empirical work has been undertaken relative to these issues. Only one study in Turkey has attempted to systematically address these issues. Erk (1989), through the use of a translog cost function for 27 public universities with 1984 data, examined the structural cost differences between

universities for the possible existence of scale economies. By using universities as the unit of analysis, the study provided some preliminary findings regarding dominant cost factors, the structural cost differences between universities in the three largest cities (i.e., Istanbul, Ankara, and Izmir) and the other universities located outside these cities, and the possible existence of scale economies. The study concluded that there were some possibilities for economies of scale as measured by MC/AC ratios and that there were substantial differences in the funding of individual universities (i.e., universities outside the three largest cities were considered materially underfunded). In separate cost estimates for universities by location, the study found that MC/AC ratios averaged 2.45 for universities in the three large cities and only .19 for universities outside of the three large cities. Assuming a correct specification of the estimating models, the study findings indicated that there were substantial diseconomies of scale taking place in universities within the three large cities and prospective economies of scale in the other universities.

The Erk study may have several limitations with respect to its methodology, data and findings. First, the study only specified the number of graduates as its output for higher education. This aggregated measure may be problematic because the number of graduates may not be a correct measure of the output of higher education when using cross-sectional data. In particular, the choice of graduates as the output measure might create biased estimation of the costs of outputs in the context of rapid expansions in enrollments and in situations where there are large numbers of drop-outs; and, in fact, both of these circumstances took place in Turkish higher education throughout the 1980s. Second, the study employed only a single-output cost function. Separate output measures for all the major higher education outputs (i.e., undergraduate and graduate teaching and research output) were not included in the cost analysis. Since the proportion of resources allocated to graduate education in Turkey is considered to be high and the size of graduate programs vary by institution, the estimated cost function probably overestimated the costs of undergraduate education. Third, the study included all public "appropriations" as the dependent variable for estimating the total costs of a university. This aggregation of all appropriations may have biased the results since almost all of the new institutions allocated an important and large portion of their annual budgets for investment in the expansion of their plant and equipment. Furthermore, appropriation and realized expenditures in any given year can and do differ substantially in the case of Turkey. Using only recurrent expenditures for a given year would provide a more accurate estimation of cost relationships in Turkish higher education. Finally, the study made no attempt to control for the quality aspect of higher education outputs and the existence of expensive

medical faculties on some campuses. Treating all universities as a homogenous set of institutions will distort the results since there can be considerable quality differences in the production technology and, in turn, the outputs among universities. In spite of these weaknesses, the study is still an important early attempt to analyze cost relationships in Turkish higher education and clearly points to the problematic nature of some current inefficiences and the prospective opportunities of economies of scale in some institutions.

Unfortunately, there have been no any other cost studies attempting to estimate cost functions in Turkey or attempts to assess the extent to which economies of scale and scope might exist within academic units and universities despite the dramatic growth in numbers of enrollments, faculty members, and academic units (i.e., faculties, schools, and two-year vocational schools) across the national system of higher education during the past two decades. Thus this study attempts to provide a more comprehensive analysis of the costs in Turkish higher education through estimation of multiproduct cost functions in search of economies of scale and scope.

Methodology

We use a four-output flexible quadratic cost function (for estimating the production effects of research, undergraduate teaching, master level instruction, and doctoral graduate education) to analyze the production and cost structures of the entire system of 28 universities in Turkey. Following the seminal work of Baumol et al (1988), and the later work by Cohn et al (1989) and Dundar and Lewis (in press), a quadratic cost function seems best to serve as the framework for analysis of marginal costs, scale, and scope economies within organizations with multiproduction outcomes, including various forms of higher education.

It should be noted that in specifying a model for estimating the relationship between the costs and multiple outputs of higher education institutions, it is difficult to select one particular functional form as being most appropriate. For instance, various forms of alternative multiproduct cost functions (i.e., translog, quadratic, and constant elasticity of substitutions) have been offered by Baumol et al. (1988) and others; and have been employed in other cost studies in higher education (Cohn et al., 1989; De Groot et al., 1990; Nelson & Heverth, 1991; Llyod et al., 1993; Dundar & Lewis, in press). Nevertheless, Baumol et al. (1988), along with several others (Cohn et al., 1989; Mayo, 1984), have recommended the use of a quadratic cost function for estimating scale and scope economies for most types of multiproduct organizations because it has been shown to comply most closely with the required features of a multiproduct production function. Its main shortcoming is the

absence of any explicit theoretical foundation for using this form in preference to any other functional form (Baumol et al., 1988, p. 453).

The Generalized Model

The quadratic cost function for the study, representing a second-order Taylor approximation around the mean, can be noted in the following generalized form:

$$C(\mathbf{y}) = \alpha_0 + \sum_i \alpha_i (y_i - \bar{y}_i) + (1/2) \sum_i \sum_j \alpha_{ij} (y_i - \bar{y}_i)(y_j - \bar{y}_j) + \varepsilon \quad (1)$$

where $C(\mathbf{y})$ is the total cost of y outputs, α_0 is the constant or fixed cost parameter, the α_i's and α_{ij}'s are coefficients, and ε is a disturbance term.

In this model no attempt is made to control for any price effect that might result from differing prices of the factor inputs. The main resource inputs for production in public universities are academic and non-academic staff and personnel expenditures which account for nearly 88% of total recurrent expenditures in the system (Dundar & Lewis, 1994). Wages in Turkey are determined by the government and do not vary by university or subject field but by seniority, academic rank and developing status of university. Accordingly, we can assume that wages are essentially constant across universities and price measures can be omitted in our cost function models.

Economies of Scale

Economies of scale are conventionally assumed to exist if total costs increase proportionately less than output as production is expanded. In the case of a multiproduct setting, a distinction can be made between two different types of economies of scale-- i.e., ray- and product-specific economies of scale.

Ray-economies of scale. Under ray-economies of scale the composition of an organization's output is assumed to remain fixed while the size of its aggregated output is allowed to vary. Ray-economies of scale assume that output is expanded proportionally along a ray emanating from the point of origin. This form of scale economy is directly analogous to economies of scale in single-product firms and it measures overall economies of scale. Ray-economies of scale can be defined over the entire output set and written as

$$S_N = \frac{C(y)}{y_i C_i(y)} \quad (2)$$

where $C_i(y) = \delta C(y) / \delta y_i$ and represents the marginal cost of producing the ith output.

Ray-economies (or diseconomies) of scale are said to exist if S_N is greater (or less) than unity. S_N can be interpreted as "the elasticity of the outputs of the relevant composite outputs with respect to the cost needed to produce them" (Baumol et al., 1988, pp. 50-51).

Product-specific economies of scale. An elasticity of economies of scale also can measure how costs change as both the output and composition of the products change. This second dimension of economies of scale is referred to as product-specific economies of scale. In this case the magnitude of a multiproduct organization's operations is assumed to change through variation in the output of one product while holding the quantities of the other products constant. The incremental cost of a multiproduct firm for producing an additional output *i*, while holding the quantities of the other products constant, can be noted by

(3) $IC(y_i) = C(y_N) - (Cy_{N-i})$

where $IC(y_i)$ denotes the total cost of producing all of the multiproduct firm outputs except the *i*th one. From this algorithm the average incremental cost due to the additional production of the *i*th output can be found by reforming the notation in the following form where

(4) $AIC(y_i) = [C(y_N) - C(y_{N-i})] / y_i = IC(y_i) / y_i$.

Product-specific returns to scale that are specific to a particular output now can be derived from the above specification as

(5) $S_i(y) = AIC(y_i) / C_i(y)$.

If in the production of teaching output, for example, there exist some product-specific fixed costs, then we would expect that product-specific economies of scale for teaching would also exist. Product-specific economies (or diseconomies) of scale are said to exist for the *i*th output when S_i is greater (or less) than unity.

Economies of Scope

The presence or absence of complementarity between outputs in production becomes a crucial matter in the case of multiple product production. Economies of scope measure the cost savings accruing to firms producing two or more products jointly as against specializing in the production of a single output. The diversity of products within a single firm or organization, known as "scope" of products, may raise efficiency by providing cost advantages in a situation in which a single firm produces a given level of output for each product level spending less than a combination of specialized separate firms. Scope economies may arise when some inputs or resources are shared in the production of two or more outputs which result in lower costs for some or all outputs.

In the case of institutional production in higher education, there can be two major types of economies arising from their joint utilization: (a) economies arising from the joint production of teaching and research and the joint production of undergraduate and graduate instruction within a university or an academic unit (i.e., college, school, or department); and (b) economies resulting from the production of a number subjects and programs jointly. In the first case, universities (i.e., as in the case of almost all Turkish universities) can be viewed as a typical multiproduct organization because they produce multiple products (i.e., undergraduate instruction, graduate teaching, research, and often public service as well) through the sharing and joint utilization of inputs such as faculty, graduate students, equipment, buildings, support staff, and the like (see Nerlove, 1972). This type of scope economies has received attention from recent studies in American higher education which statistically confirmed the existence of economies of scope in the joint production of undergraduate teaching, graduate studies, and research (Cohn et al., 1989; De Groot et al., 1991; Nelson & Heverth, 1993; Dundar & Lewis, in press).

In the second case, scope economies can also arise when universities produce a number of programs and subjects (e.g., arts, science, social science, health science, engineering and the like) jointly rather than separately (e.g., Lloyd et al., 1993). The source of economies of scope for this case type would be largely dependent upon jointly used inputs such as central administration and support services, libraries, and laboratories. Additionally, cross-college teaching production could be an important source of such economies because fewer courses would be provided by other colleges within a university instead of employing full-time teaching staff within each college. This type of scope economies has been examined by Lloyd et al., (1993) for Australian universities. They reported the existence of economies of scope in the production of various subjects jointly rather than separately.

The focus of this study will be on attempting to examine for any economies of scope that might result from the joint production of teaching and research or from the joint production of graduate education with undergraduate training, rather than the joint production of various subjects across faculties. The latter case of scope economies probably does not exist in Turkey's higher education institutions simply because very little inter-college sharing of joint resources takes place and because students take all of their instruction and course work almost exclusively within only one college.

Economies of scope simply measure whether the cost of producing two or more products jointly would be less expensive than the cost of producing them separately. Economies (or diseconomies) of scope are said to be present when

(6) $C(y) \geq (\geq) C(y_{N-t}) + C(y_t)$

where $C(y_t)$ is the cost of producing the product set t, and $C(y_{N-t})$ is the cost of producing all other products other than those in the product set t. The degree of economies of scope can be noted for a product set t by

(7) $S_G = [C(y_t) + C(Y_{N-t}) - C(y)] / C(y)$

where S_G denotes the degree of global economies of scope. If $S_G \geq 0$ then cost advantages accrue for producing the output bundles jointly.

Specification of Study Variables and Data Sources

Total cost variables. The dependent variable for our total cost model includes all the recurrent costs for the "faculty" (or college) production of teaching and research. In this regard, the study follows procedures used in most other similar studies through the use of institutional expenditures as the measure for costs of higher education. Accordingly, research funding for externally sponsored research, and transfer and capital investment expenditures are excluded. Private costs to students are also excluded since the study focuses on faculty/college and institutional cost comparisons.

Central administration and support service expenditures were also omitted from our estimates since our basic unit for analysis was the "faculty" or college. But the costs of graduate schools were included. We allocated such costs to the individual faculties according to their shares of graduate students in total enrollments. It is recognized that the exclusion of central costs does, of course, lead to an underestimation of the costs of instruction and research. However, the focus of this study is on the total costs of "faculties" and the extent of possible economies of scale and scope at this level in various subject groupings. The implications of this study from such a disaggregated perspective is likely to be more important for policy makers in Turkish higher education as they compare the costs of faculties by subject area and between institutions.

Total costs were the sum of costs for all inputs employed for the production of teaching and departmental research activities in an academic year in the ith faculty. These costs comprise the following expenditure categories: (1) annual total faculty and non-academic staff wages and fringe benefits; (2) annual expenditures for services and supplies; (3) annual expenditures for equipment; and (4) other unspecified recurrent expenditures.

Data on expenditures (costs) for this study were obtained from "1991 Final Account Law" publications for each of the 28 public universities in Turkey (Ministry of Finance, 1992). These publications provide the latest, most detailed and reliable data on appropriations to and expenditures of universities and their subunits (e.g., faculties and

schools) in various categories.

Output variables. The four outputs for the cost functions of the study were specified as (1) the number of annual undergraduate level students in the ith university or faculty; (2) the number of annual master level students in the ith university or faculty; (3) the number of annual doctoral level students in the ith university or faculty; and (4) the number of publications (i.e., journal articles and books) by the ith university or faculty.

It is noteworthy that the number of full-time students at the three teaching levels (i.e., undergraduate, master, and doctoral) were identified and used as proxies for teaching output for a given academic year. Since all students are considered to be full-time students, identification of the number of students as teaching output variables do not pose a problem as compared with similar studies in the United States or in the United Kingdom where there are large numbers of part-time students. Additionally, the number of students produced by each body of faculty is a relatively accurate proxy for teaching when measuring across colleges since Turkish universities generally provide little cross-faculty or inter-college production of teaching.

All data on undergraduate enrollments were obtained from the "1991-92 Higher Education Statistics" published annual by the Student Selection and Placement Center (OSYM, 1992a). Graduate enrollments (i.e., master and doctorate enrollments) for each faculty were derived from the unpublished "1991-92 Graduate Student Statistics" provided by the Student Selection and Placement Center (OSYM, 1992b).

The data on graduate enrollments may be problematic because the number of graduate students were not reported by faculty (i.e., colleges) within each university but by program. We calculated the number of graduate students for each college from their related graduate programs. Two problems appeared in our calculation of the number of graduate students by college. First, if there were more than one faculty/college in a particular subject within the same university, we were unable to determine the number of graduate students by college in that particular field. As a consequence, some faculties were omitted from our sample. Secondly, in a few cases there were interdisciplinary graduate programs or programs which were not offered as undergraduate programs. Thus, we were again unable to determine which faculty (or college) produce which graduate students. In such cases, we omitted those graduate programs from the sample.

Finally, the only reliable proxy available for measuring research output was the number of research publications (i.e., books and journal articles) produced by each university and faculty (or school) in 1990. Research publications were obtained from an unpublished study reported in "The 1990 Higher Education Publication Catalog" by the Higher

Education Council (YOK, 1993)

Quality of output variables. The accuracy of results from a cost study in higher education depends upon the assumption that all institutions in the analysis have similar objectives and produce a relatively homogenous "output" (Getz & Siegfield, 1991). This assumption requires that we only focus on institutions in higher education with similar emphases on teaching and research. It would be inappropriate, for example, to compare the cost structures of two-year vocational schools with most four-year programs because of very different outputs (and the need for differing resource inputs) in both types of programs. With our focus on four-year faculties (i.e., colleges) as our unit of analysis, we assume that all are drawn from a relatively homogenous sample because all Turkish universities are organized as research universities with similar objectives and outputs. Nonetheless, we may have a problem because the quality of outputs may be different between university or faculty/college even if the quantity of the output is the same. As such, if there are quality differences in the production of teaching and research between universities and faculties, the results might be biased in the absence of controls for these quality differences.

Unfortunately, there are no standard and accepted measures for the quality of higher education outputs which might enable us to directly control and measure for these effects on costs. Nevertheless, in an attempt to test for this possible effect we collected students' university entrance exam scores as a proxy to represent variations in institutional quality. We selected this measure because we believe that students who took the exam probably chose a particular program and institution based on their perception about the quality of the university and its faculty (see Tierney, 1980). Thus it is assumed that such institutional selectivity at the undergraduate level can be used as a proxy measure for the educational quality provided at a specific institution. To test this assumption, the study obtained university entrance exam scores for programs and faculties from OSYM (1992c). Unfortunately, preliminary review of these undergraduate quality indexes in several forms indicated that they did not discriminate well across the institutions selected, and this measure subsequently was dropped from the study.

Other control variables. Location-specific dummy variables were used as a measure of control over input prices (i.e., largely personnel expenditures) for the analysis of university faculties in our three field groupings. There are large variations in unit costs between universities in the three large cities and those located outside these cities and there are several differing hypothesis concerning location of a university which might affect the costs of higher education in Turkey. Costs per student in universities located outside the

three large cities might be higher because of higher personnel expenditures, their small scale, or because of higher proportions of administrative and support service expenditures. We know, for example, that universities in the developing regions of the country indeed do spend more for each graduate (Erk, 1989). It was expected that location-specific control variables could control for any differences between institutions that might arise from differing funding, definitions of outputs, and production technology.

The Study Design and Unit of Analysis

In this study, the basic unit of analysis is the faculty (or college). Faculties and schools in Turkish higher education are the fundamental organizational units of universities and are relatively autonomous, make decisions on the curriculum, determine academic degree standards, recruit faculty, and largely determine the technology for the production of their output. Accordingly, through the four output quadratic model defined above, we estimated several multiproduct faculty (college) cost functions for the social sciences, engineering, and health science fields of study. Selection of faculties in these three fields was based on the reports of the Final Account Laws published by the Ministry of Finance (1992). These publications reported budget and expenditures under these three subject groups. However, if expenditures were reported jointly with another school, these faculties were omitted from the samples. The total final sample across the 28 public universities included 186 faculties from the social sciences, engineering and the health sciences. The groupings included the following faculties:

Social Science:	Education, Economics and Administration, Law, Theology, Journalism, Arts and Science.
Engineering:	Engineering, Engineering and Architecture
Health Science:	Dentistry, Pharmacy, Medicine.

Possible Data and Design Problems

A number of potential problem areas emerge relative to the data and design of our study. First, it is important to remember that most of our data comes from the 1991-92 academic year. We know, for example, that in 1992 many parts of the higher education system experienced a dramatic expansion in resources. Thus, our results need to be interpreted cautiously in the context of this dynamic academic year.

Second, not all educational outcomes may be accurately measured in the study. The four most commonly expected outputs of higher education institutions are undergraduate instruction, graduate education, research, and public services and all but services are

addressed in the study. However, there are typically no clear-cut measures to indicate the quality, and in some cases even the true quantity, of all these outputs. Despite the fact that value-added measures for teaching and research outputs are most desired, it is very difficult, if not impossible, to obtain direct measures characterizing such outputs of higher education institutions across large numbers of similar institutions. Accordingly, we like almost all other similar cost studies, employed only approximate or proxy variables for their measurement by using the number of students and publications as our proxies for teaching and research.

In addition to the largely known teaching and research products of public universities, such institutions also have outcomes in public service and outreach activities. Public service may be particularly important for large-research oriented universities since most are also expected to transfer knowledge outside their institutions. Ideally we would have liked to have had some index or proxy for the public service produced by our institutions, but these data were not available. As a consequence, our model did not adequately account for public service.

Third, higher education institutions as non-profit organizations are perceived by some observers as not minimizing their costs. This results from the fact that not only the quantity of outputs, but also their qualities are desirable outcomes (James & Rose-Ackerman, 1986). For instance, when Turkish universities had the option to make decisions about their numbers of admitted students during the 1970s, they decided to reduce the number of students due to concerns about declining educational quality (Gedikoglu, 1985). It has been argued by some observers that, rather than minimizing their costs, higher education institutions spend all their available revenue for the sake of increasing quality and prestige (Galvin, 1980). Bowen (1981) defined this economic behavior of higher education institutions as a "revenue theory of costs," at least in the short run. Although Brinkman (1990) has argued that this explanation for the cost behavior of higher education institutions has some validity, it is probably an overstatement without substantial empirical evidence. Similarly, Verry (1987) has observed that "the assumption that education institutions act as cost minimizers is not absurd; after all, the teachers and administrators in such institutions do have certain objectives and are constrained by limited resources, so that departures from cost minimization imply that whatever objectives are being pursued will not be attained to the full extent possible" (p.408).

Fourth, our use of student entrance exam scores as a proxy for institutional quality would have been problematic in any case because the variation in university entrance exam scores might be related to factors other than institutional quality. We can note that

programs whose graduates are highly demanded in the labor market have significantly higher scores across all the universities. Programs, for example, in medical colleges, law, and computer engineering are highly demanded in the labor market. In these programs, university entrance exam scores were remarkably high and there was little variation in scores across universities or programs in these areas. In addition, universities with English as their language of instruction appear to be highly selective without regard to their educational resources (i.e., academic staff, libraries, and educational facilities and equipment) compared with other older Turkish language universities. In recent years, the demand for university graduates who speak at least one foreign language (preferably English) has materially increased in the rapidly changing economy. Finally, universities located in the three largest cities generally have higher demand because of a larger population pool and the attractiveness of social and cultural environments in a large city (even if they might not have a higher quality of teaching or research compared to other universities). As a result, our measure for institutional quality might not have been very sensitive to qualitative differences between universities in any case.

Lastly, it should be noted that the utilization of quadratic models in the estimation of cost functions in higher education can be criticized for their lack of theoretical foundation in linking with production in higher education. The production function of departmental and college level activities in higher education is still largely perceived as a "black-box." It is not explicitly known which inputs and what kinds of technical requirements are necessary for producing optimum outputs in order to derive a mathematically sound cost function (Bowen, 1981; Brinkman & Leslie, 1986; Gilmore, 1990; Hopkins, 1990). In light of these difficulties in dealing with costs, a common approach has been to use statistically best fitting techniques in order to find an appropriate functional form (Brinkman, 1990). The use of the specific quadratic model in this study appears to be the "best fit" for our purposes.

Estimating the Cost Functions

The variables included within the study and their estimated coefficients for the basic quadratic model for the three field groupings are summarized in Table 1. All three models have reasonably high explanatory powers with adjusted R-square terms accounting for 76%, 96%, and 97% of the variations in total faculty costs in the social science, engineering, and health science faculties, respectively. The results reported through all three models in Table 1 imply that there are uniform set-up costs for most departments. In a multiproduct cost function, economies of scale will be dependent upon the magnitude of the fixed costs.

[Insert Table 1 about here]

In the case of the health science faculties, two important features of the sample should be noted. First, hospital expenditures were not included in medical faculty expenditures in order to insure that the health science group could be considered a more homogenous group of faculties relative to their production technology. Second, we did not differentiate graduate output as between master and doctorate levels, because master level education either does not exist or was concentrated in only a few fields in the health science faculties. Thus the model was estimated as a three-output model rather than as a four-output model as in the case of the other groups.

The presence of statistically significant negative parameters for any quadratic terms found within the models of Table 1 indicate that for the production of those outputs the cost function is likely concave and generative of economies of scale. Noting the significance of the quadratic terms for undergraduate instruction across both the social science and engineering fields in Table 1, it appears that there are important opportunities for economies of scale through the expansion of undergraduate instruction in these fields across the system. This, however, does not appear to be similarly true at this level of analysis for either graduate education or research activities where none of the coefficients are found to be significant across any of the three fields (except for research in the health sciences).

In Table 1 we note that the squared coefficient for undergraduate teaching is significant, negative, and clearly suggestive of scale economies in social science faculties. Scale economies for doctorate instruction were also evident, although the coefficient was not statistically significant. It is not clear from the estimated model for the social sciences that there existed scale economies for other outputs.

For engineering faculties, the results reported here suggest that scale economies possibly exist for all four outputs because the estimated coefficients for their quadratic forms were all negative. However, the significance levels of individual coefficients were low and it may be premature to suggest much about the extent of scale economies with this model alone.

In the case of the health science faculties there were appropriately negative coefficients for the quadratic terms for both graduate instruction and research production, indicating prospective economies of scale in these two areas. Undergraduate instruction in the health sciences was both positive and significant indicating that economies probably could be gained through enrollment reductions in this area.

Cost Complementarities

The interactive terms found within all the models in Table 1 also give us early insight into the prospects for whether there might also exist cost complementarities and prospective economies of scope. Negative coefficients for the interaction terms, for example, would suggest the cost-effectiveness of their joint production.

Cost complementarities and economies of scope appear to exist in the joint production of graduate education with research activities across both the social science and engineering fields, and in the case of the health sciences such complementarity exists between research and undergraduate instruction. The statistically significant negative interaction terms for master level instruction and research across both the social sciences and engineering fields suggest that the production of these outputs jointly would decrease costs. The positive interaction terms for doctorate level instruction and research was surprising and indicates an increase in costs from their joint production, at least at current levels of such production and instructional technology in Turkish universities. One possible explanation might be that doctorate students are not actively utilized in the production of scientific research publications in most subject groupings, even if the majority of them are hired as research assistants. Rather, they may be assigned to assist in other administrative or instructional activities.

Somewhat surprisingly, we found virtually no evidence to support the conventional wisdom about cost complementarities between graduate and undergraduate education in any of the fields. In fact, what evidence we do have suggests possibly the opposite effects. We found, for example, positive and statistically significant interaction terms for the joint production of master level instruction with undergraduate training in both the social science and engineering subject groupings, suggesting the existence of diseconomies of scope in their joint production. Although there appear to be weak economies of scope for the joint production of undergraduate and doctorate students (wherein the signs were appropriately negative), none of these coefficients were found to be statistically significant. Overall, the results appear to be somewhat negative in terms of the effect of graduate education on the production and costs of undergraduate instruction. These results are clearly in contrast to similar studies in the U.S. where economies of scope were found in the joint production of graduate education with both undergraduates and research products (Cohn et al., 1989; De Groot et al., 1991; Dundar & Lewis, in press).

Estimating Multiproduct Economies of Scale and Scope

Preliminary examination of the coefficients of the multiproduct cost functions in Table 1

were suggestive of the existence of economies of scale for some of the products. In order to examine for the existence of multiproduct economies in more detail, we turn now to an estimation of the average incremental and marginal costs of our subsample fields along with more closely examining their prospects for scale and scope economies utilizing the previously described multiproduct cost concepts. It should be noted that the analysis focuses first on the cost behavior of a "typical faculty" operating around sample means; and then later we examine at the extremes of the sample and estimate their degrees of scale and scope economies.

Average Incremental and Marginal Costs

The estimated cost functions reported in Table 1 were used to estimate the average incremental (AIC) and marginal (MC) costs reported in Table 2 for each type of output at the sample output means in each of the three faculty groupings. From our reported results in Table 2 we can draw several inferences with respect to the costs of outputs across all three fields. First, the costs of providing instruction generally increase by academic (or degree) levels. While undergraduate instruction has generally the lowest costs, doctoral level instruction at the college level has the highest costs (generally in terms of both average incremental and marginal costs). This supports our earlier findings that the average graduate student costs more than the average undergraduate student even though there are differences in the magnitude of such costs by academic level and fields. In comparison of the costs of outputs between fields, we can also observe that the average incremental cost of undergraduate instruction was lower for social science subjects than for engineering and health science subjects. Average incremental cost for graduate instruction was clearly the highest within the engineering fields.

[Insert Table 2 about here]

Ray-economies of Scale

From the estimated coefficients of the cost functions reported in Tables 1, the degrees of economies of scale at given points of production for the various output sets were computed. As defined earlier, these point estimates (i.e., S_i) represent the degrees of ray-economies (or diseconomies) of scale; and if the point estimate is greater than unity, then ray-economies of scale are assumed to exist for the output set. Increasing the level of production for each output set from the mean level would result in an increase in cost-effectiveness. Table 3 reports the results from our computation of degrees of both ray-and product-specific economies of scale for faculties in the three fields producing at their sample output means. Since a multiproduct cost function behaves best at the point of

mean approximation in an output sample, the sample output means are used to calculate our returns to scale. Ray-economies of scale for universities and the social sciences, engineering, and heath sciences all were estimated to be highly positive and greater than one (i.e., 3.102, 2.434 and 1.340, respectively, at their sample output means). These findings suggest that the potential for ray-economies of scale exist for the "typical" faculty in all three subject groupings operating at their sample product mean and that cost advantages would accrue from producing more output in fixed proportions. Such academic units producing at their output means have clear incentives to expand their production of outputs to exploit existing potential scale economies.

[Insert Table 3 about here]

From Table 3 we also discover that ray-economies of scale also appear to be greater than one and highly positive for all colleges at the lower levels of their output means (i.e., 50% of their sample output means). This finding also suggests that expanding output levels proportionally for all small institutions and faculties would also increase efficiency in the production of teaching and research, assuming, of course, that we can hold the quality levels of the outputs constant.

On the upper level of production, we discover that ray-economies of scale continue to exist even at around 200% of the sample output means for faculties in the social science and engineering subjects. The exception is in the health science faculties. The principle implication from such a finding is clear! Expanding the size of faculties in engineering and the social sciences up to at least 200% of the current sample output mean would likely lead to increased efficiency. This is obviously a controversial finding in the case of Turkish higher education since there are already complaints about the existence of quality declines due to the large increases in enrollments over the past decade. Such expanded levels for the health sciences, on the other hand, would lead to the emergence of diseconomies of scale.

Product-specific Economies of Scale

The study also computed product-specific economies of scale for each output at the sample output mean for the academic units and the results also are reported in Table 3. As noted above, if the product-specific economy of scale point estimate (i.e., S_i) is greater than one, then that specific product has ascribed economies of scale and increasing the level of production for that individual output would result in enhanced efficiency. Product specific economies of scale for undergraduate instruction exist for faculties in social science and engineering subject groupings but not in the health sciences at the sample

output mean. Universities will achieve greater efficiencies by "some" increase in the levels of their undergraduate enrollments in these two fields, regardless of the levels of the other outputs.

We found the existence of product-specific economies of scale for some graduate instruction (i.e., master and doctoral level teaching), although there were exceptions in the social sciences and engineering. Our findings in Table 3 suggest that Turkish universities may achieve material efficiencies by increasing the enrollment levels of their doctoral study programs in both the social and health sciences and in master studies programs in engineering regardless of the levels of the other outputs. Any increase in efficiency resulting from an increase in master level students in the social sciences or doctoral level students in engineering should be due to only proportional increases in all products and then to the existence of ray-economies of scale. As previously noted, the current levels of graduate education are low at almost all universities and this results in substantial inefficiency. With respect to research output we found no prospects for scale economies at the sample outputs in any of the three fields.

Further insight into scale economies can be gained by estimating product-specific scale economies at various alternative levels of production. Table 3 presents estimates which indicate mixed results across the three subject groupings. In the production of social science faculties, for example, product-specific scale economies do appear to exist for only doctoral level teaching at both lower and higher levels of output. Increasing production of this output at all levels independent from the other outputs would result in an increase in efficiency. We also found the existence of product-specific diseconomies of scale at upper levels of output for the production of undergraduate education. As a consequence, any increase to a higher production level (e.g., up to 200%) in social science faculties in the production of undergraduate teaching should be undertaken only with a similar joint increase in other products.

The cost behavior of the engineering faculties profiles a different picture with respect to the presence of product-specific economies of scale. We found evidence of product-specific economies of scale at both low and high levels for undergraduates and master teaching outputs. The health science faculties were found to have product specific economies of scale in the production of doctoral instruction at both lower and higher levels of output but not for the highest levels of undergraduate instruction.

In summary, we found strong ray-economies of scale in the production of our four model outputs across almost all the social science, engineering, and health sciences colleges. It is clear that the majority of Turkish universities have not yet exhausted their

optimal scale of plant and operations. From a policy perspective the recent expansion in the number of new institutions and faculties, with limited attention to the potential existence of scale economies in existing institutions, has undoubtedly contributed to further inefficiencies in the system. Most of these inefficiencies probably arise in new doctoral level programs in the social and health sciences and new undergraduate and master level programs in engineering. As a result of the further expansion of programs and institutions in 1992, it is likely that the existing inefficiencies have worsened.

Economies of Scope

Production in Turkish higher education typically exhibits joint production since a number of products are produced jointly and the costs of production are not allocated based on any single type of output (e.g., the number of students at each level or research). Economies of scope in higher education production suggest that a single institution or faculty/college can produce a given bundle of output (i.e., UND, MAST, DOCT, and RES) in a less costly manner than in specialized teaching or as independent research institutions. This can be empirically tested by examining for economies of scope in the production of teaching and research outputs. In the four-product case of this study, economies of scope exist with respect to the product sets of y_1, y_2, y_3, and y_4 (i.e., UND, MAST, DOCT, and RES, respectively) if

(8) $C(y_1, y_2, y_3, y_4) \leq C(y_1, 0, 0, 0) + C(0, y_2, 0, 0) + C(0, 0, y_3, 0) + C(0, 0, 0, y_4)$.

The degree of global economies of scope (S_G) for our study can be noted as

$$(9) \qquad S_G = \frac{C(y_1, 0, 0, 0) + C(0, y_2, 0, 0) + C(0, 0, y_3, 0) + C(0, 0, 0, y_4) - C(y_1, y_2, y_3, y_4)}{C(y_1, y_2, y_3, y_4)} .$$

Estimated degrees of global economies of scope calculated at the sample means and for various output levels for each faculty subject groupings are presented in Table 3. The results indicate that for all faculties in the fields of the social sciences, engineering and health sciences there appear to be material opportunities for economies of joint production from combining the production of teaching and research at the sample output mean and at lower levels of output. The S_G's in all three fields are estimated to be positive and the costs of producing UND, MAST, DOCT, and RES simultaneously are smaller than the costs of producing them separately. Only when the joint production of all outputs was expanded to 200% and above the typical institution sample output mean in engineering did scope

economies turn negative.

Discussion

The principle concern of this study has been to examine whether economies of scale and scope existed in Turkish public universities at faculty/coliege levels in three broad fields. And if they did exist, to what extent and with what effect? Results from our estimates using multiproduct quadratic cost functions suggest a number of important and practical implications for policy makers in Turkish higher education. First, our results indicate that it is possible to examine the cost structures of Turkish universities through the use of multiproduct cost models. Our model had high explanatory power and illustrated material differences in structural form (i.e., production technology) for producing teaching and research outputs across differing faculty subject groupings.

The inclusion of average university entrance scores as a proxy for institutional quality did not appear to affect the explanatory power of the basic multiproduct quadratic model. Yet, our statistically insignificant parameter for institutional selectivity does not necessarily suggest the insignificance of output quality. Rather, it should be interpreted as more likely resulting from our relatively homogeneous sample of universities with respect to their funding since all the institutions in the sample are comparable public research universities and treated as equal in the allocation of state funding. Therefore it can be argued that scale and output-mix are the main determinants in Turkey of the costs of producing teaching and research outputs.

Our findings suggest a number of generalizations about costs within the public university system of Turkey. These findings include the propositions that (a) average incremental and marginal costs are generally highest for graduate instruction and research outputs and lowest for undergraduate instruction, (b) of the fields we examined, the social sciences generally have the lowest costs across almost all categories of outputs with health sciences faculties generally having the highest costs, (c) although costs generally follow levels of instruction, there are some notable exceptions, and (d) most faculty/college outputs have shared resource use and costs.

The estimated results indicate that the estimated average incremental costs of doctoral level programs are much higher than undergraduate teaching and research outputs (except in engineering faculties). On the other hand, our findings also argue that excluding the costs of both graduate teaching and research outputs from any institutional cost study will necessarily result in incorrectly overestimating the costs of other outputs due to their shared costs. Results from this type of multiproduct cost function study, for

example, could be helpful in public financing and designing differential level tuition policies for universities in Turkey.

The findings of this study concerning economies of scale and scope in Turkish higher education are broadly consistent with the findings of other recent multiproduct cost functions for U.S., U.K., and Australian universities, with the notable exception of our finding that little cost complementarity appears to exist between undergraduate and graduate level of instruction in Turkey. Our results are strongly suggestive that substantial economies of scale and scope are present in the production of teaching and research in Turkish universities.

It is noteworthy that the majority of programs in Turkish universities are operating at less than their optimal and most efficient size. Consequently, most faculties/colleges in Turkey will gain efficiencies with expansion in both their teaching and research outputs, although the degrees of scale economies differ by field group and level of instruction. While all faculties in the study operating at an output range smaller than their sample output mean would gain efficiencies due to an appropriate increase in the level of their outputs, even ray-economies of scale do exhaust at some point with large increases in production. Size effects would be greater and more dramatic with expansion from lower levels of output in all three fields. Product-specific economies of scale are also present at most relevant levels of production for both teaching and research outputs across most fields, although again some exceptions were noted.

Finally, findings in the study clearly suggest that there are substantial cost advantages associated with the multiproduct nature of Turkish higher education. These economies of scope arise from the joint utilization of faculty, administrators, support staff, and equipment and services for the production of both teaching and research outputs. This implies that it is more cost-effective to produce instruction and research jointly than separately in all three fields. Accordingly, the findings in this study support the commonly understood (but seldom empirically verified) notion that the costs of producing graduate education along with departmental research, are significantly less than producing them separately. Nourishing specialized and free standing research centers outside and independent of university instruction will likely result in less efficiency than in the joint production of the same outputs in Turkish public universities. This finding is particularly important in light of the existence of a large public research organization outside the universities (i.e., TUBITAK), as well as the emergence of a number of other public research organizations within various ministries.

An important question is whether the utilization of doctoral students in the joint

production of other outputs results in any efficiencies. According to higher education regulations, graduate students are employed as research assistants who are supposed to help senior faculty in their research activities. However, utilization of research assistants as undergraduate teaching assistants is also a widespread phenomenon in most developing Turkish universities, particularly in those where there are serious faculty shortages. Research assistants are commonly employed as teaching assistants in Turkey, even if they are not paid for their teaching work (Erk, 1989). The fundamental policy question becomes: Are there any cost-efficiencies due to such joint production of graduate education with the other two outputs? This question has been long argued in the United States where graduate students are utilized heavily in the production of undergraduate instruction particularly in large research universities. In the U.S. recent empirical studies have supported this hypothesis by finding cost complementarities in the joint production of graduate education and undergraduate education (see, for example, Cohn et al., 1989; de Groot et al. 1991; Dundar & Lewis, in press).

In the case of Turkish higher education, however, such joint supply effects had not previously been examined. Our findings indicate the appropriate negative signs of interaction terms in Table 1 illustrating that there probably does exist some weak joint supply effect for producing undergraduate and doctoral students jointly in the social science and engineering field groupings, but unfortunately these effects were not statistically significant. Moreover, our study did not find any complementarity between undergraduate teaching and doctoral studies in health science faculties, which suggests that colleges in the health sciences do not use graduate students as much as social science and engineering colleges in the production of undergraduate teaching.

Based on the findings reported in this study, several specific public policy recommendations can be identified.

- Given the prospective economies of scale found within many existing institutions and programs, it is recommended that public policy priorities be directed to expanding most existing institutions and programs rather than the creation of new programs. For efficiency reasons, targeted priority for expansion should be given to those programs operating outside the major cities and those currently operating within a range of production below their cohort sample means.
- Given the prospective economies of scope found within most existing institutions and programs, especially the interactive and joint effects of graduate education and research, it is recommended that public policy priorities be directed to the nourisment of research funding in higher education rather than the independent development of free standing

research centers outside of higher education.

• Given the use and current deployment of graduate students in the instructional activities of most Turkish universities, materially less evidence was found with regard to prospective cost complementarity and economies of scope between graduate and undergraduate instruction. If the increasing concerns about quality in the current graduate offerings of many programs prove to be real (YOK, 1989; Williamson, 1987), then strong consideration should be given to encouraging differentiated missions for differing institutions, especially for those with high graduate education costs and low program quality. In short, it does not appear to be cost-effective to insist that all institutions continue to persue the development of graduate programs. Although product-specific economies of scale were indicated for several levels of graduate education, these findings generally were not statistically significant nor were they found universally across all the fields. Even beyond cost considerations, removing graduate education from small, low quality programs makes intuitive good sense as well. Some universities and programs with low graduate enrollments and low quality should be encouraged to specialize in only undergraduate instruction as is the current case in many other countries.

The findings reported in this study relative to the likely effects of scale and scope economies in Turkish higher education are particularly timely given the recent and projected future expansion of higher education in Turkey. To date, not enough attention has been paid to the possible existence of scale and scope economies. Higher education in Turkey will continue to suffer from existing inefficiencies until more public policy and institutional attention is given these issues.

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Table 1 - Estimated Parameters for the Quadratic Cost Functions

Variables	Units of Analysis		
	Social Sciences (t-statistic)	Engineering (t-statistic)	Health Sciences (t-statistic)
Constant	7,885198*	14,808,927*	12,982,270*
	(17.13)	(10.87)	(14.63)
UND	2,744.20*	5444.8*	8,191*
	(7.61)	(5.67)	(5.03)
MAST	413	22,227*	-
	(0.11)	(2.54)	
DOCT	21,645**	-48,533**	23,764**
	(1.80)	(-1.92)	(1.93)
RES	20,898	36,378	65,404*
	(1.51)	(1.32)	(4.24)
UNDSQ	-0.615*	-1,2513**	8.947*
	(-4.13)	(-1.75)	(4.84)
MASSQ	5.89	-86.87	-
	(0.47)	(-1.19)	
DOCTSQ	-188.00	-833.2	-89.38
	(-1.03)	(-0.91)	(-1.14)
RESSQ	(26.5)	-1,011.1	-249.8**
	(0.14)	(-1.35)	(-1.71)
UND*MAST	7.076*	57.46*	-
	(2.91)	(2.21)	
UND*DOCT	-3.726	-58.74	2.11
	(-0.52)	(-1.07)	(0.11)
UND*RES	(-7.594	-32.87	-39.31**
	(-0.98)	(0.91)	(-1.85)
MAST*DOCT	-24.74	-164.3	-
	(-0.29)	(-0.51)	
MAST*RES	-205.82*	-876.7*	-
	(-3.68)	(-2.62)	
DOCT*RES	682.2*	3,563*	66.1
	(2.64)	(2.58)	(0.58)
N	108	29	49
F-statistic	25.43	54.40	204.14
Adj. R^2	0.762	0.964	0.974

Notes: Educational expenditures are expressed in Turkish Liras.

* Significant at the 1% level or better, 2 tailed-test.

** Significant at the 10% level or better, 2 tailed-test

Table 2 - Comparison of Average Incremental and Marginal Costs of Individual Outputs at the Output Mean

Fields	AIC_{y_1}	MC_{y_1}	AIC_{y_2}	MC_{y_2}	AIC_{y_3}	MC_{y_3}	AIC_{y_4}	MC_{y_4}
Social Sciences	2274	1148	6173	7095	23324	13191	12399	13273
Engineering	9992	7460	76209	56942	-142900	-206889	15572	19886
Health Sciences*	14385	23475	-	-	23515	15954	11522	-8011

Notes: All units of measure are in thousands of Turkish Liras. AIC = Average Incremental Costs; MC = Marginal Costs; y_1 = Undergraduate Students; y_2 = Master Level Students; y_3 = Doctorate Level Students; and y_4 = Published Articles and Books.

*Graduate level students in the health sciences related faculties have master and doctoral students combined.

Table 3 - Degrees of Economies of Scale and Scope for Alternative Output Bundles

Percentage of Output Means	Ray Economies of Scale	Product-Specific Economies of Scale				Global Economies of Scope
		UND	MAST	DOCT	RES	
Social Science Related Faculties						
50%	3.902	1.298	0.877	1.290	0.974	2.117
100% Output Mean	3.102	1.980	0.870	1.768	0.934	1.662
200%	4.665	-4.038	0.866	5.278	0.960	1.148
Engineering Faculties						
50%	3.451	1.119	1.243	0.749	3.150	1.920
100% Output Mean	2.434	1.338	1.338	0.690	-0.783	1.107
200%	2.110	1.523	1.420	0.649	0.068	-0.352
Health Science Related Faculties*						
50%	2.183	0.712		1.190	1.340	1.217
100% Output Mean	1.340	0.612		1.474	-1.438	0.862
200%	0.921	0.530		2.857	0.520	0.579

Notes: UND = Undergraduate students; MAST = Master level students; DOCT = Doctorate level students; RES = The number of articles and books.

*For health science related faculties the master and doctorate level outputs are aggregated as a graduate output and the cost function is estimated for three outputs (i.e., undergraduate education, graduate education and research).